



## Report for Working Group 2

### Design Education in Civil and Environmental Engineering

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# **Report for Working Group 2: Design Education in Civil and Environmental Engineering**

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## **Introduction**

The theme for the second working group was design education in civil and environmental engineering. Issues discussed during this meeting included the current state of the art of civil design education, the importance of civil design education, tools and techniques that can be used to build design competencies, the importance of balancing hard and soft skills, and the role that culture and context play and will continue to play in civil design in the future.

## **Current State of Design Education in Civil and Environmental Engineering**

The current state-of-the-art of design education in civil and environmental engineering seems to be characterized by a lack of formalized design processes that can be taught. Frameworks, like those of Axiomatic Design Theory, Integrated Energy Design, and Architectural Design can inform civil design education. However, none are totally suitable. It seems increasingly common for civil engineering programs to experiment with design education. DCEE participants reported on several design programs which include cornerstone, keystone, and capstone design subjects. These serve both as an educational vehicle and as a platform to better understand and formalize the civil design process. However, there is an ever-present risk of simply teaching the same material to the students with increasingly difficult problems. A more formalized and deeper understanding of design in CEE would create more opportunities to teach a variety of design methods and perspectives. This would also help to develop a curriculum that would spiral outward and allow students to try out different design methods as they progress.

## **The Importance of Design as a Recruitment and Retention Vehicle**

One working group participant noted that first year students in civil and environmental engineering are often very enthusiastic, creative, and open minded.

However, these characteristics deteriorate over the course of the undergraduate program because traditional CEE curricula tend to train students to look for and provide a single solution to all problems. Exposing them to open ended problems at this point can cause them to withdraw because of a fear of proposing the ‘wrong’ solution. Therefore, it is important that students are exposed to design projects early in their engineering education so their open-mindedness and creativity remain with them throughout their careers. Another way to encourage this attitude is to expose students to design traditions and design ‘heroes’ of CEE (for example, through Bill Addis’s 3000 Years of Design Engineering and Construction). Heroes provide a legacy which is needed to gradually transform conservative professors and help students to appreciate a project-based, design approach. The historical examples also help students to develop a better vocabulary to discuss design methods in CEE.

## **Reverse Engineering in Civil Design Education**

Reverse engineering has a long tradition in mechanical design as a vehicle to teach students about the structure of technical artifacts. Design history is often taught in architecture and sometimes also included in civil engineering education. However, increasing this type of work and having students involved more deeply by doing reverse design and deconstructing the design process may help to encourage both their analytical and design skills. For example, students can be asked to find how the design process proceeded to a certain point or to investigate alternative designs that were or could have been pursued.

## **Best Practices from Other Fields**

Mechanical engineering and architecture provides a reservoir of design methods and educational practices which can be taught or used in CEE design courses. However, the fundamental differences between the professional circumstances should be kept in mind

when they are used. For example, in civil engineering each project is (in principle) developed from scratch. In addition, in mechanical engineering design teams work with mass production as an aim, and thus more can be invested in each design process.

### **Defining the Competencies of Civil Designers**

Much of the working group discussion focused on identifying the necessary attitudes and competencies of civil designers. For example, it was noted that professional civil engineering firms routinely stress the importance of hand sketching over computer rendering because it facilitates communication during meetings. It was also observed that civil engineers do not currently have a culture of “push back”. Instead, the input from the architects is often treated as a given rather than something to be negotiated. In addition, civil engineers may need to have a greater awareness of the upstream and downstream actors in the overall design and construction process.

### **Cultural Context and Techno-Socio-Economic Considerations**

The working group participants stressed the importance of culture and context in civil and environmental engineering and thus the need to prepare students to be culturally sensitive and contextually aware. For example, one participant noted that developing countries often do not have sufficient local expertise and so many hire consultants from abroad. Unfortunately, these engineers often do not know how to deal with the cultural differences, how to communicate with the local team, or how to appreciate the environment.

This poses a conundrum for civil and environmental design. In general, engineers do not study people while other types of designers, including architects, often do. To address these issues, the engineers must develop new competencies. However, there is insufficient room in the curriculum to add this dimension.

### **Multidisciplinary Design Teams**

Much of the working group discussion focused on the importance of multidisciplinary design teams and preparing students to function within them. Most contemporary design processes in industry include collaboration between different professions to some extent. However multidisciplinary design processes do not take up much space in most CEE curricula.

In the US, the engineer is a consultant to the architect, not a partner. Traditional CEE curricula train the students for this professional role. As a result, most CEE students will never experience a

multidisciplinary design process before they graduate. This has consequences for the professional design processes later on; most new civil and environmental engineers have no experience in how to influence the design processes, especially in the early stages. On a more positive note, there is a strong tradition of civil and environmental engineers as partners in a design team instead of as consultants in specific offices like Arup, Buro Happold, Schlaich Bergermann and Partners, etc.

Teaching civil and environmental engineers to collaborate in multidisciplinary teams is best done in actual collaboration. Architects are one of the major groups of potential collaborators for civil and environmental engineers. Developing shared projects between schools of architecture and CEE programs is an obvious possibility. The Technical University of Denmark and National Taiwan University both have experience doing so. However, research in the field is needed to determine, for example, how the first meeting between engineers and the architects should be organized. How can they avoid slipping into traditional roles where the architects create ideas and engineers optimize?

A successful multidisciplinary design process is very dependent on attitudes and people skills. It is well known that collaborative design projects can serve as a vehicle for teaching and developing soft skills (communication, teamwork, project management, etc.) in engineering students. Collaborative personal skills can also be subject to a progression in the curriculum. For example, curricula can be extended to include international experiences and other cultural contexts.

It was observed that a new multidisciplinary common ground is being developed by the fact that the same set of simulation tools are being used simultaneously by different groups of professionals for different purposes. Having a common set of tools can enhance the communication skills of the students and help them to better understand each other's work.

### **Recommendations**

The working group made two recommendations. First, a mapping of the design methods that are relevant to CEE should take place. The DCEE forum provides a platform where research in design education in CEE could take place and the methods appearing from the mapping could be tried out. Thus, this would be a suitable venue to undertake that mapping. Second, the working group recommends that further research in multidisciplinary design processes in CEE be undertaken and used to form the basis of more projects with this focus in CEE curricula.